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We demonstrated a novel sources of pulsed terahertz radiation and x-rays which have ultrashort pulse duration and high intensity; this source is based on emission from ultrashort, laser-heated gases and solids. We have examined the propagation of high intensity (up to 10^{19} W/cm^2) ultrashort (100 fs) laser pulses in dense gases; this work has application to a variety of studies involving high power laser pulses such as harmonic generation, x-ray lasers, and laser wakefield accelerators. We studied schemes for new x-ray lasers; they involve rapid recombination of highly ionized atoms (produced by multiphoton ionization) followed by lasing on Ly-α x-ray transitions. We developed a new Thomson scattering technique using multiple, ultrashort laser pulses; these studies were done in multiphoton ionized plasmas of interest to the construction of new x-ray lasers. We have examined conditions for pumping recombination x-ray lasers using multiphoton ionized gases. We have examined the non-Maxwellian energy distributions in multiphoton ionized gases. Finally, we examined both the coherent and incoherent emission from short-pulse laser excited clusters. This latest work has established that sub-wavelength sized clusters can be a source of intense plasma emission, and that clusters are a source of harmonics from laser-matter interaction.

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"X-Rays from High-Intensity, Short-Pulse Interactions"

No. F49620-93-1-0356

award period covered 6/1/93 - 9/30/96

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Summary of work done

During the contract period we made significant progress in areas of high-intensity laser interaction with plasmas. The students involved included:

Susanna Gordon (through 9/93)
Ernest Glover (through 11/93)
Alan Sullivan (through 9/94)
Evert Lipman (through 5/94)
Tom Donnelly (through 6/96)
David Ponce-Marquez (through 9/96)

All of these students are US citizens, have satisfactory records, and at the time of support, graduate students in the Ph.D. program in the Physics Department at UC Berkeley. I used the grant primarily to support Tom Donnelly, but to augment the fellowships and related support of the other students. Essentially, the grant has been used to support 1.5 FTE graduate student.

Our work involved
-- development of ultrashort pulse x-ray sources
-- generation of subpicosecond, unicycle electromagnetic pulses
-- propagation of intense, short pulse lasers in plasmas
-- new x-ray lasers
-- new high-intensity, short pulse lasers
-- diagnosis of multiphoton ionized plasmas
-- interaction of intense short pulse lasers with clusters

Our work resulted in twenty-two publications which are listed below; five of these have not previously been listed on a technical report. We demonstrated a novel sources of pulsed terahertz radiation and x-rays which have ultrashort pulse duration and high intensity; this source is based on emission from ultrashort, laser-heated gases and solids. We have examined the propagation of high intensity (up to 10^{19} W/cm^2) ultrashort (100 fs) laser pulses in dense gases; this work has application to a variety of studies involving high power laser pulses such as harmonic generation, x-ray lasers, and laser wakefield accelerators. We studied schemes for new x-ray lasers; they involve rapid recombination of highly ionized atoms (produced by multiphoton ionization) followed by lasing on Ly-α x-ray transitions. We developed a new Thomson scattering technique using multiple, ultrashort laser pulses; these studies were done in multiphoton ionized plasmas of

interest to the construction of new x-ray lasers. We have examined conditions for pumping recombination x-ray lasers using multiphoton ionized gases. We have examined the non-Maxwellian energy distributions in multiphoton ionized gases. Finally, we examined both the coherent and incoherent emission from short-pulse laser excited clusters. This latest work has established that sub-wavelength sized clusters can be a source of intense plasma emission, and that clusters are a source of harmonics from laser-matter interaction.

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3. S.P. Gordon, R. Sheppard, T. Donnelly, D. Price, B. White, A. Osterheld, H. Hamster, A. Sullivan, R.W. Falcone, "Short Pulse X-Rays from Porous Targets," in *Shortwavelength V: Physics with Intense Laser Pulses*, M.D. Perry and P.B. Corkum, eds. (OSA, Washington, DC, 1993) pp. 203-205.

4. A. Sullivan, S. Gordon, H. Hamster, H. Nathel, R.W. Falcone, "Propagation of Intense, Ultrashort Laser Pulses in Plasmas," in *Shortwavelength V: Physics with Intense Laser Pulses*, M.D. Perry and P.B. Corkum, eds. (OSA, Washington, DC, 1993) pp. 40-44.

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11. H. Hamster, A. Sullivan, S. Gordon, R.W. Falcone, "Short-Pulse Terahertz Radiation from High-Intensity Laser-Produced Plasmas," Phys. Rev. E **49**, 671 (1994).

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